華中科技大學

课 程 报 告

课　　　程　光电科学认知实践初步

任课教师　[redacted]

学　　　号　[redacted]

姓　　　名　[redacted]

专　业　班　[redacted]

院（系、所）　光学与电子信息学院

日　　　期　**2018 年 7 月 31 日**

Abstract

This lesson is set to lead us to learn more about some science progress or advanced results in terms of optical and electronical information. Also, it can give us a platform to think about the majors which we are studying and to trigger new ideas about it. At the end of my essay, I also list my own thoughts and suggestions to this course.

Key Words: papers advanced results suggestions

Contents

1 Foreword

1.1 Brief introduction to International Day of Light

The information following is extracted from the official website of UNESCO : https://en.unesco.org/commemorations/dayoflight and the official website of IDL: https://www.lightday.org/.
The International Year of Light and Light-based Technologies 2015 (IYL 2015) was a United Nations observance that raised global awareness of the achievements of light science and its applications, and their importance to humankind. Under the leadership of UNESCO, more than 13,000 activities took place in 147 countries to reach an audience estimated at over 100 million. The International Day of Light will be held on May 16th every year, the anniversary of the first successful operation of the laser in 1960 by physicist and engineer, Theodore Maiman. The laser is a perfect example of how a scientific discovery can yield revolutionary benefits to society in communications, healthcare and many other fields.

Light plays a central role in our lives. On the most fundamental level, through photosynthesis, light is at the origin of life itself. The study of light has led to promising alternative energy sources, lifesaving medical advances in diagnostics technology and treatments, light-speed internet and many other discoveries that have revolutionized society and shaped our understanding of the universe. These technologies were developed through centuries of fundamental research on the properties of light starting with Ibn Al-Haythams seminal work, Kitab al-Manazir (Book of Optics), published in 1015 and including Einsteins work at the beginning of the 20th century, which changed the way we think about time and light.

The International Day of Light celebrates the role light plays in science, culture and art, education, and sustainable development, and in fields as diverse as medicine, communications, and energy. The celebration will allow many different sectors of society worldwide to participate in activities that demonstrates how science, technology, art and culture can help achieve the goals of UNESCO building the foundation for peaceful societies.

1.2 Our Flashing Activity

On May 16, our class, together with the class of optoelectronic information science and technology for exemplary engineer, hold the so-called Flashing Activity, which shows the fascination of optical and electronical information shallowly to the students in other departments.

1.3 Information concerning Wuhan National Laboratory For Optoelectronics

The information is extracted from the official website of WNLO There are 5 major research areas in WNLO, namely optoelectronic devices and integration, laser and terahertz technology, energy photoelectron, biomedical photonics, information storage and optical display. Wuhan National Laboratory for

Optoelectronics is co-founded by the Ministry of Education of Peoples Republic of China, Hubei Provincial Government and Wuhan Municipal Government. It is one of the initial five national laboratories authorized in November 2003 by the Ministry of Science and Technology of Peoples Republic of China. The feasibility plan for its construction was approved by in November 2006. The laboratory is managed by Huazhong University of Science and Technology in collaboration with Wuhan Research Institute of Posts and Telecommunications, Wuhan Institute of Physics and Mathematics affiliated to the Chinese Academy of Sciences, and Huazhong Institute of Electro-Optics.

2 Main contents of the essay

2.1 Further information about International Day of Light

As we all know, light is playing a more and more important role in our daily life. In the past many years, the Nobel prize has been awarded to research results which concerning, more or less, to light or laser. The table under gives a brief sketch of several Nobel Prizes related to light.

Year	laureate	Rationale
1921	Albert Einstein	discovery of the law of the photoelectric effect
1930	Chandrasekhara Venkata Raman	for his work on the scattering of light
1981	Bloembergen and Schawlow	contribution to the development of laser spectroscopy
2009	Charles K. Kao	the transmission of light in fibers

These awards are a powerful illustration of the important role that light plays in the field of physics today. It should be said that the study and research on the characteristics of light may largely change the way we understand and use information communication and energy in the future. Therefore, the establishment of ”International Day of Light” is of great significance.

2.2 Something more about visiting WNLO

After a terms study at HUST. Ive gained some of the knowledge about WNLO, but never paid a visit to it. Hence, Im very keen at visiting the laboratory. There comes a promotional film first, introducing to us the basic background and the process of its developing to us. What impressed me the most was the achievements of Professor Luo Qingming’s team. This is the first time that a fine brain vascular map containing arteries, veins, arterioles, and venules has been systematically constructed and identified throughout the brain. We know that the brain is an extremely rich organ of blood vessels, and many lesions are associated with structural abnormalities in the blood vessels of the brain. Moreover, the cerebral blood vessels are various in shape and are easily interlaced. Accurate three-dimensional imaging must therefore be used to demonstrate complex vascular anatomy. None of the previous technologies can achieve this. Professor Luo Qingming’s team has devoted decades to the development of microscopic optical section tomography, and in 2017, systematically constructed and identified the fine cerebrovascular vessels containing arteries, veins, arterioles and venules in the whole brain map. Although it is just a shallow cognition for that the construe cannot be that accurate in such a short time, but it has given me a surprise successfully. I cant even imagine how the brain map of a mouse can be constructed even very roughly, let alone a so detailed and complete result. Hence, these achievements impressed me most. Also, Ive learned something about the laser technology, and its application in national defense, medication, and even exploration. Whats more, this visit gave us a general idea of how to carry out research and how to come up with some creative ideas. Those professors who work at WNLO gave me a source of energy to work harder at my lessons, and to set out a purpose of achieving one of the useful significant results, at least taking part in it, in the future.

2.3 Study of my mentor's research interest

My mentor majors in the area of high power solid-state laser, optoelectronic device and laser technology. In my essay, I want to write some basic knowledge or backgrounds about high power solid-state laser, and something about the other two fields concisely.

2.3.1 Basic knowledge about high power solid state laser

Introduction High power solid-state laser has been playing a significant role in the fields of military and common life, which is the reason why it has become the hot spot in nowadays research work. Its meaningful for that it could provide the same level of power but being smaller, having a short wavelength, easy to couple compared with the carbon dioxide laser. Hence it is beneficial to learn something about the high power solid state laser now and in the future. [1] [2]

Using the flash pumping technology, the first solid-state laser was also the first laser to be successfully demonstrated by Maiman. The gain medium of SSL is a crystal rod or crystal plate (sometimes extremely thin) doped with rare earth elements (such as lanthanum, cerium, lanthanum, etc.); different dopants can be used to generate a series of different output wavelengths, but generally located in the near-infrared region. One of the most common and used crystalline materials today is yttrium-doped aluminum garnet with a corresponding laser wavelength of 1064 nm. The inefficiency of flash-pumping technology has made SSL difficult for a long time, until the use of diode lasers as pump sources has greatly improved the electro-optic efficiency of SSL, and the potential of military applications for mobile platforms has emerged. At the turn of the century, diode-pumped solid-state lasers are growing rapidly. Goodno et al developed a 415W continuous wave DPSSL in 2001 with a light-to-light conversion efficiency of 30%. Later, a phase-locked zigzag slab laser array with a power of up to 19 kW was developed. DPSSL currently has the highest level of 105kW phase-locked laser system.

In this system, seven 15kW main oscillation power amplifier laser chains are coherently synthesized. As shown in Figure 2, the (DC) electro-optical conversion efficiency is 19.3%. The average beam quality is 2.9 and the run time is over 300s. One branch of the SSL field that shows a bright future is a thin disk laser. Giesen et al. have proposed this concept nearly 20 years ago, and Giesen and Speiser have a very good topic on this type of SSL. Disc lasers have achieved power outputs in excess of 35 kW while maintaining good beam quality. In the recent ”Daily Demonstration Laser” project, the US Navy demonstrated the ship's defense using the SSL system built by Northrop Grumman, destroying the engine of a small vessel a mile away. In the ”High Energy Liquid Laser Area Defense System” project, a series of thin disk laser amplifiers are immersed in the coolant to use this unique approach to alleviate the waste heat management problems that are common in high power SSL systems.

The main problem with SSL is the deposition of waste heat within the crystal, creating a thermal gradient and causing beam quality problems. A variety of heat dissipation methods have been tried in high-power SSL, such as increasing the crystal heat dissipation area (slats, thin disk lasers), pre-cooling (heat capacity lasers), fluid flow heat dissipation (air cooling, water cooling), etc. The direction and practical application prospects also depend on the degree of improvement in waste heat management. [3]

Useless heat in solid-state lasers In the early days of laser development, people tried their best to increase the output power. But people soon discovered that brightness is more important than output power in many important applications. Since the brightness of the laser is proportional to the power P, it is inversely proportional to the fourth power of the beam quality factor . Therefore, due to the adverse thermal effect, at a certain power level, as the output power continues to increase, the brightness of the laser does not increase and decrease as the beam quality decreases. This is a difficult problem that has long plagued the scientific community.

Since the birth of the first laser pumped by a gas discharge lamp in 1960, people have been struggling with the harmful thermal effects associated with lasers. This is a thorny issue that has achieved significant results but has not been fully resolved. In summary, three aspects of work have been carried out:
1) Reducing the useless heat entering the working medium is the most fundamental and most desirable method. Doped filter, heat absorbing glass sleeve, dielectric film concentrating cavity, potassium xenon lamp and laser diode pumping have been used. The use of LD pumping is by far the most effective way to reduce the useless heat of solid-state lasers. Compared to conventional pumping lamps, the components in LD pumped solid-state lasers (DPSSL) are ”solid-state” and are therefore also referred to as all-solid-state lasers. The use of LD pumping greatly reduces the useless heat in solid-state lasers, but it has not been completely eliminated. If the useless heat can be completely eliminated, the beam quality and output average power of the solid laser will be greatly improved, but such a method has not been found so far. We can also reduce useless heat from:
(1) using low-heat pumping in existing four-level systems;
(2) using quasi-three-level systems;
(3) developing new working media (such as the ability to achieve radiation balance), to fundamentally avoid the generation of useless heat; in addition, is also studying the use of nonlinear effects (such as optical parametric amplification) for power amplification, because this is not based on energy level transitions, so

theoretically can avoid the use of unwanted heat.
2) Derived useless heat with the most effective and least harmful method. That is to say, since it cannot be stopped, we must use the most efficient method to derive these useless heat. At the same time, it is also important to note that it is necessary to try to avoid distortion in the working medium caused by heat dissipation or increase.
3) Reduce and compensate for the adverse effects caused by unwanted heat.

The last point to note is that the useless heat that cannot be circumvented by the above measures will cause adverse effects such as laser beam quality degradation, output power limitation, and damage to the working medium. And researchers have achieved very fruitful results in this regard:
(1) Optimize the design of the pumping structure to achieve a uniform gain distribution in the working medium, which is the basis for obtaining a high-efficiency, high-quality laser beam;
(2) Aligning the heat flow caused by cooling with the direction of the laser to reduce the effect of thermal distortion on the beam quality;
(3) Reasonably design the geometry of the working medium;
(4) Increase the output power by using deviation, loss and reuse;
(5) Design a reasonable cavity shape to compensate for thermal effects;
(6) Using the heat capacity working mode and compressive stress design to improve the thermal stress damage threshold of the working medium;
(7) Reasonably design doping concentration, pumping strength and distribution to reduce thermal gradient;
(8) Corrected beam distortion using stimulated Brillouin scattering (SBS) phase conjugate mirrors, deformable mirrors, etc.

All of the above techniques have been developed in the study of overcoming the harmful heat in solid-state lasers and are still evolving. In order to further reduce the useless heat, the working mode of the all-solid-state laser and the geometry of the working medium have new and even revolutionary changes, and a variety of effective practical techniques have been developed.[2]

Design and requirements for high power solid state lasers The main technical specifications for the design of high-power solid-state lasers are (1) output power (2) beam quality (3) laser efficiency. Solving the steady-state heat conduction equation and the stress-strain equation in a one-dimensional model,The temperature T of the rod-like medium at which the radius R can be found is parabolically distributed in the radial direction:

$$T(r) - T_0 = \frac{QR}{2\lambda_r} + \frac{Q}{4k}(R^2 - r^2) \tag{1}$$

where T_0, Q, λ, k are basically Coolant temperature, injected thermal power per unit volume, surface heat transfer coefficient and thermal conductivity.
Stress component

$$\sigma_{rr} = \frac{Q}{16M_s}(r^2 - R^2), \sigma_{\theta\theta} = \frac{Q}{16M_s}(3r^2 - R^2), \sigma_{zz} = \frac{Q}{8M_s}(2r^2 - R^2) \tag{2}$$

Material constant

$$M_s = \frac{(1-\nu)k}{\alpha E} \tag{3}$$

where ν, α, k are respectively poisson's ratio, coefficient of thermal expansion, and Young's modulus. at the surface $\sigma_{rr} = 0$,

$$\sigma_{\theta\theta} = \sigma_{zz} = 8\frac{Q}{M_s}R^2 \tag{4}$$

Thermal shock parameters R_s and stress fracture limits of materials σ_{max} satisfies

$$R_s = \sigma_{max} M_s \tag{5}$$

Then the maximum pump power (regardless of the radius of the rod) is

$$P_{max} = 8\pi l R_s \tag{6}$$

Use (6) ,we can find the output power. In order to calculate the beam quality, it also involves knowledge of the lens and the cavity, which is omitted here. [1]

2.3.2 Brief Introduction about optoelectronic device and laser technology

About optoelectronic device Tip: The following content is extracted from Wikipedia.
1.Photoelectric or photovoltaic effect, used in:
(1)photodiodes (including solar cells)
(2)phototransistors
(3)photomultipliers
(4)optoisolators
(5)integrated optical circuit (IOC) elements
2.Photoconductivity, used in:
(1)photoresistors
(2)photoconductive camera tubes
(3)charge-coupled imaging devices
3.Stimulated emission, used in:
(1)injection laser diodes
(2)quantum cascade lasers
4.Lossev effect, or radiative recombination, used in:
(1)light-emitting diodes or LED
(2)OLEDs
7.Photoemissivity, used in
(1)photoemissive camera tube
Important applications of optoelectronics include
(1)Optocoupler
(2)Optical fiber communications

laser technology Laser technology is a topic which is so widely-covered, hence in my short essay I can't tell much about it. So it is just a very brief introduction.
The laser has the characteristics of good monochromaticity, strong directivity and high brightness. There are thousands of laser working substances that have been found, ranging from soft X-rays to far-infrared. The core of laser technology is laser. There are many types of lasers, which can be classified according to

different methods such as working substance, excitation mode, operation mode and working wavelength. According to different application requirements, some special techniques are adopted to improve the beam quality and single technical index of the output laser. The more widely used unit technologies include cavity design and mode selection, frequency multiplication, tuning, Q-switching, mode-locking, frequency stabilization and Amplification technology, etc. In order to meet the needs of military applications, the following five laser technologies have been developed:
(1) laser ranging technology. It is the first laser technology to be practically applied in the military. At the end of the 1960s, laser range finder began to be equipped with troops, and various types have been developed and produced. Most of them use yttrium aluminum garnet lasers with a range accuracy of 5 meters. Because it can quickly and accurately measure the target distance, it is widely used in reconnaissance measurement and weapon fire control systems.
(2) laser guidance technology. Laser guided weapons have high precision, simple structure, and are not susceptible to electromagnetic interference, and they play an important role in precision guided weapons. In the early 1970s, the laser navigation bombs developed by the United States were first used in the battlefield in Vietnam. Since the 1980s, the production and equipment of laser guided missiles and laser guided projectiles have also increased.
(3) laser communication technology. The laser communication has large capacity, good confidentiality and strong anti-electromagnetic interference capability. Optical fiber communication has become the development focus of communication systems. Airborne, spaceborne laser communication systems and laser communication systems for submarines are also under development. (4) strong laser technology. A tactical laser weapon made of a high-power laser can blind the human eye and disable the photodetector. The use of high-energy laser beams may destroy military targets such as aircraft, missiles, and satellites. Tactical laser weapons for blinding, air defense, etc., are nearing the practical stage. Strategic laser weapons for anti-satellite and anti-intercontinental ballistic missiles are still in the exploratory stage.
(5) laser simulation training technology. Military training and combat exercises with laser simulation equipment, no ammunition consumption, safe training, and realistic effects. A variety of laser simulation training systems have been developed and produced, which are widely used in shooting training and combat exercises of various weapons. In addition, laser nuclear fusion research has made important progress. Laser separation of isotopes has entered the stage of trial production. Laser fuzes and laser gyros have been put into practical use.

2.3.3 My suggestions to this course

To prepare my essay, I've read a lot of papers on the Internet such as Google Scholar etc.My knowledge now cannot provide me enough understanding of these papers, hence I can just copy their theories and simplify them in my own language. I do think the right way to carry out this course is to let us enter our mentors laboratory in our own, and listen to their consture of the fields which they majored in.Also we can go to some companies connected with optical and electronical technology to feel them in a more real and vivid way.What's more, we can also take some tasks to complete to raise up our knowledge level in practice and connect theory instead of just talking about theory,which can't give us much reward.

References

[1] Lv Baida, Hu Yufang, Cai Bangwei, Xu Shifa, and Lv Houtao. High power solid-state lasers. *Laser and Infrared*, (5):33–42, 1991.

[2] Zhou Shouhuan, Zhao Hong, and Tang Xiaojun. High average power lser diode pumped solid-state laser. *Chinese Journal Of Lasers*, 36(7):1605–1618, 2009.

[3] Luo Wei, Dong Wenfeng, Yang Huabing, Xu Pengcheng, and Tang Zhikai. Development trend of high powe lasers. *Laser and Infrared*, 43(8):845–852, 2013.